

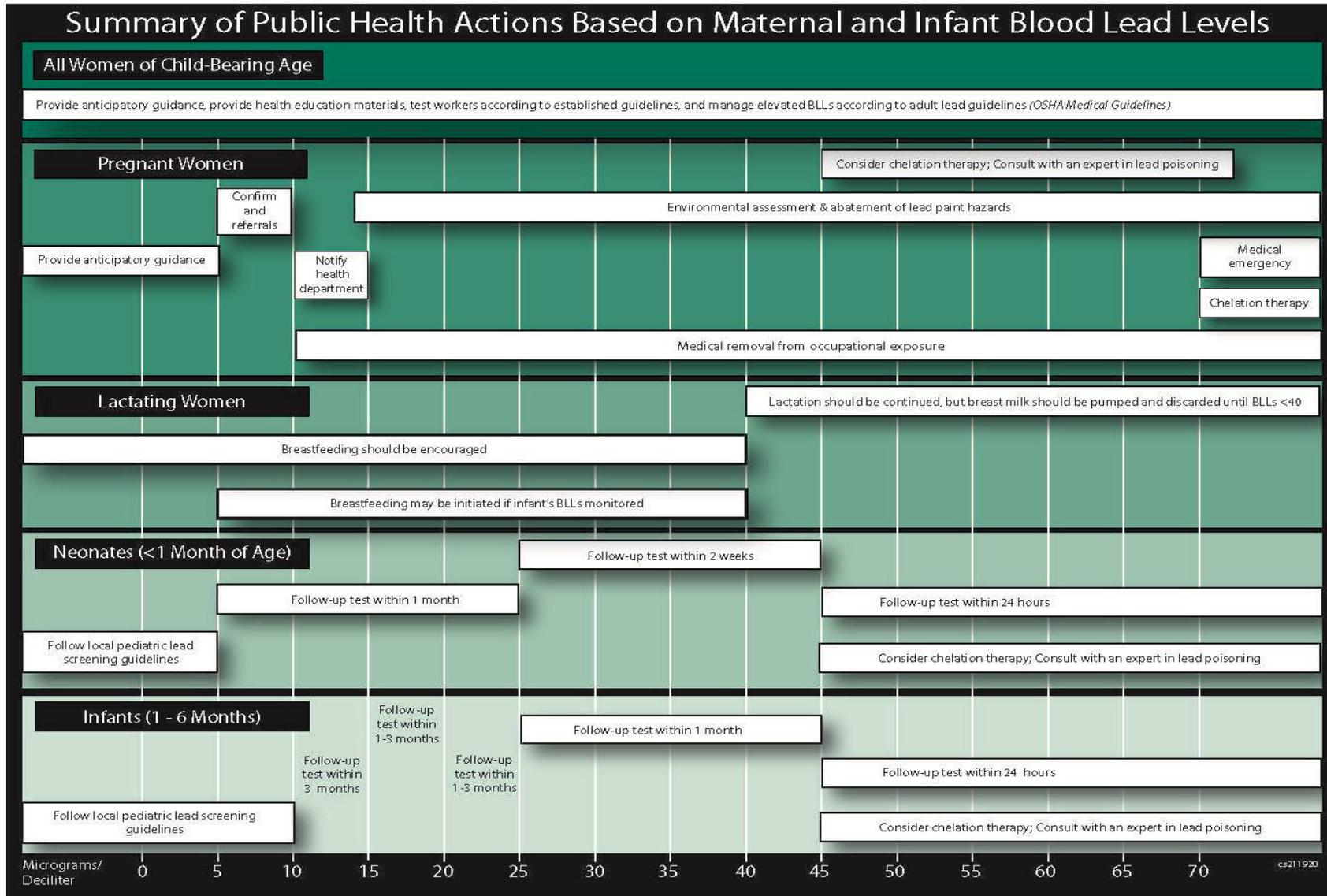
Chapter 11

Lead Toxicity and Reproductive Health, Pregnant and Lactating Women, and Fetal and Infant Development

Contents

| | |
|--|-------|
| In Brief: Summary of Public Health Actions on Maternal and Infant Blood Lead Levels (CDC, 2010)..... | 11.2 |
| Introduction | 11.3 |
| Lead Toxicity and Reproductive Health..... | 11.3 |
| Effects on Fetal and Infant Growth and Neurodevelopment | 11.4 |
| Prenatal Assessment and Intervention..... | 11.6 |
| Key Recommendations to Prevent or Reduce Lead Exposure | 11.7 |
| Blood Lead Testing in Pregnancy and Early Infancy | 11.7 |
| Follow-up Blood Lead Testing for Pregnant and Lactating Women and Infants..... | 11.7 |
| Recommended Actions for Pregnant and Lactating Women with Lead Exposure | 11.9 |
| Breastfeeding and Lead Exposure | 11.10 |
| Lead in Breast Milk | 11.10 |
| Infant Dose of Lead from Breast Milk | 11.11 |
| Recommendations for Lactating Women with Lead Exposure..... | 11.12 |
| References | 11.14 |

In Brief: Summary of Public Health Actions on Maternal and Infant Blood Lead Levels (CDC, 2010)



Introduction

Lead is ubiquitous in the human environment as a result of industrialization. Lead has no known physiologic value, and has long been recognized as a reproductive toxin in both men and women. Despite improvements in environmental policies and significant reductions in U.S. average blood lead levels, lead exposure remains a concern for pregnant and lactating women, particularly among certain population subgroups at increased risk for exposure.

Recent National Health and Nutrition Examination Survey (NHANES) estimates suggest that almost 1 percent of women of childbearing age (15-44 years) have blood lead levels greater than or equal to 5 mcg/dL (Centers for Disease Control and Prevention 2008, unpublished data). There exists good evidence that maternal lead exposure during pregnancy can cause fetal lead exposure and can adversely affect both maternal and child health across a wide range of maternal exposure levels. Maternal lead exposure and lead poisoning history should be considered in prenatal care assessments.

Over 90 percent of lead in the adult body is stored in bones and teeth, and the remaining lead is stored in blood and soft tissue. Lead stored in bones has a long half-life (20-30 years) and can be mobilized into blood and soft tissues during periods of heightened bone turnover, such as pregnancy and lactation, and can adversely affect the fetus or newborn. Women and their infants may be at risk for continued exposure long after exposure to external environmental sources has been terminated. Lead is similar in chemical structure to calcium, and competes with it for absorption in the gastrointestinal tract and deposition in bone.

Today, the workplace is often the source of lead exposure for adults. Toxic BLLs should not occur if workplace exposures are in compliance with Occupational Safety and Health Administration (OSHA) regulations. For more information on workplace exposure and adult blood lead poisoning, contact the Bureau of Environmental and Occupational Health, Wisconsin Division of Public Health (608-264-9829) or OSHA at www.osha.gov.

In November 2010, CDC issued [guidelines for the identification and management of lead exposure in pregnant and lactating women](#). Some of the most salient of the guidelines are included in this chapter – effects of lead on reproductive health, pregnancy and lactation and the fetus and newborn, health actions, and initial and follow-up testing schedules for pregnant and lactating women and their infants.

Lead Toxicity and Reproductive Health

For centuries, exposure to high concentrations of lead has been known to pose health hazards. Recent evidence suggests that chronic low level lead exposure also has adverse health effects in both adults and children and no blood lead threshold level for these effects has been identified. CDC has not identified an allowable exposure level, level of concern, or any other bright line intended to connote a safe or unsafe level of exposure for either mother or fetus. Instead, CDC is applying public health principles of prevention to intervene when prudent (see Public Health Actions at the beginning of this chapter).

In adult males, chronic lead exposure can result in decreased sex drive, impotence, and sterility (Rodamilans et al. 1988). Abnormalities in sperm, including count and motility, have also been found. There is no consistent evidence that male lead exposure gives rise to negative effects on a fetus (Jensen et al., 2006).

Lead may adversely impact sexual maturation in the developing female and may reduce fertility. Although studies are limited, there is some suggestion that blood lead at relatively low levels may lead to alterations in onset of sexual maturation (Wu et al., 2003) and reduced fertility (Guerra-Tamayo et al., 2003). These findings underscore the importance of considering sensitive markers of human reproductive ability in relation to lead exposure.

Maternal lead exposure during pregnancy has been linked to both gestational hypertension and preeclampsia. In a review article (Kennedy et al. 2012) researchers found positive associations between lead exposures in pregnant women and the development of preeclampsia in two studies of mothers whose median blood lead levels were greater than 10 mcg/dL. Among pregnant women with blood lead levels less than 10 mcg/dL, no association between maternal blood lead and preeclampsia was found (Rabinowitz et al., 1987).

In contrast, hypertension seems to begin developing at lower blood lead levels. Among pregnant women with lower blood lead levels (median less than 10 mcg/dL), increasing blood lead levels were predictive of increased probability of developing gestational hypertension in two out of three studies. Studying pregnant women with higher blood lead levels, median greater than 10 mcg/dL, researchers found a significantly increased prevalence of hypertension (Magri et al., 2003, Sowers et al., 2002, Vigele et al., 2004).

The evidence suggests that increased risk for spontaneous abortion appears to be associated with blood lead levels ≥ 30 mcg/dL (Borja-Aburto et al., 1999, Lamadrid-Figueroa et al., 2007). There is limited evidence to suggest that maternal blood lead levels less than 30 mcg/dL are associated with an increased risk for spontaneous abortion. Maternal lead exposure may increase the risk for preterm delivery (Torres-Sanchez et al., 1999, Jelliffe-Pawlowski, 2006), lower birth weight (Gonzalez-Cossio et al., 1997, Zhu et al., 2010), shorter birth length and smaller head circumference (Hernandez-Avila et al., 2002, Rothenberg et al., 1999). The available data are inadequate to establish the presence or absence of an association between maternal lead exposure and major congenital anomalies in the fetus (Jackson et al., 2004).

Effects on Fetal and Infant Growth and Neurodevelopment

Both pregnancy and breastfeeding can cause a state of physiologic stress that increases bone turnover of lead. Lead stored in the bone as a result of childhood lead poisoning can move into the blood, increasing the mother's blood lead level and passing to the fetus. Pregnancy-related hormonal changes affect calcium metabolism and can also cause lead to leave the bone and enter the blood. Thus, women's blood lead levels typically rise during pregnancy.

Lead binds tightly to red blood cells, enhancing transfer from maternal circulation through the placenta to the fetus. Placental transfer begins as early as the 12th week of gestation. As in adults, the lead can be found in fetal blood, soft tissue, and bone. The fetus is more sensitive to lead because the fetal blood-brain barrier is more permeable, the developing central nervous system is more vulnerable, and the fetus has less bone tissue for sequestering lead. Fetal exposure to lead is usually determined by measuring lead from umbilical cord blood samples taken at birth. These samples are highly correlated with maternal blood levels, with fetal BLLs estimated to be 80 to 90 percent of the maternal levels.

Because elevated maternal blood lead is available to the fetus, it can negatively impact fetal development. Lead is known to interfere with synaptogenesis and, perhaps, with pruning (Goldstein, 1992) in the developing brain. It interferes with stimulated neurotransmitter release

at synapses in the cholinergic, dopaminergic, noradrenergic, and GABAergic systems (Cory-Slechta, 1997; Guilarte et al., 1994). It substitutes for calcium and zinc as a second messenger in ion-dependent events. These disturbances in neurotransmitter release would thus be expected to disrupt the normal organization of synaptic connections (Bressler and Goldstein, 1991).

The brain is protected from large molecular compounds in the blood by the blood-brain barrier, created by tight junctions between endothelial cells in cerebral blood vessels (Goldstein, 1990). The development of this barrier function begins *in utero* and continues through the first year of life (Goldstein, 1990). The brain is one of the target organs for lead. Lead exposure *in utero* and during the first year of life may disrupt the development of the blood-brain barrier.

Evidence is clear that *in utero* exposure to low levels of lead can affect infant and child growth and neurodevelopment. More recent prospective studies have included children with lower prenatal exposures, and continue to detect inverse associations with neurodevelopment.

- Wasserman et al., (2000) found independent adverse effects of both prenatal and postnatal blood lead on IQ among Yugoslavian children aged 3-7 years. Prenatal lead exposure was associated with a deficit of 1.8 IQ points for every doubling of prenatal maternal blood lead after controlling for postnatal exposure and other covariates.
- In a study conducted in Mexico City, Gomaa et al., (2002) found that umbilical cord blood lead and maternal bone lead levels were independently associated with covariate-adjusted scores at 2 years of age on the Mental Development Index score of the Bayley Scales of Infant Development with no evidence of a threshold.
- Maternal blood lead level early in the second trimester and in the third trimester was a significant predictor for some measures of mental and psychomotor development at age 2 years (Wigg et al., 1988).
- In another study in Mexico City, maternal plasma lead level in the first trimester was a particularly strong predictor of neurodevelopment at age 2 (Hu et al., 2006). When this cohort was assessed at 24 months, inclusion of umbilical cord blood lead level in the model indicated that it was a significant predictor of psychomotor development even when analyses were restricted to children whose did not exceed 10 mcg/dL (Tellez-Rojo et al., 2006).
- Schnaas et al. (2006) found that prenatal lead exposure around 28-36 weeks gestation (third trimester) was a stronger predictor of reduced intellectual development at ages 6–10 years than second trimester (12-20 weeks) exposure, but that study did not measure prenatal exposure in the first trimester of pregnancy.
- Jedrychowski et al. (2008) found a higher risk of scoring in the high-risk group on the Fagan Test of Infant Intelligence at age 6 months when umbilical cord blood was higher.
- Low-level umbilical cord blood lead levels can also negatively impact responses to acute stress (Gump et al., 2008).

Other research has found that young children with pre-natal lead exposure have lower scores on verbal IQ components (Wasserman et al., 2000), impairment in hearing and motor development (Rothenberg et al., 1994), and increases in learning disabilities and attention deficit disorders (Ris et al., 2004).

Prenatal Assessment and Intervention

The CDC does not recommend blood lead testing of all pregnant women in the United States. Instead, the CDC recommends that state or local health departments identify populations at increased risk for lead exposure (see Figure 11.1) and provide guidance about community-specific risk factors to assist clinicians in determining the need for blood lead testing for identified populations or for individuals at risk.

Figure 11.1. Risk Factors for Lead Exposure in Pregnant and Lactating Women

Recent immigration from or residency in areas where ambient lead contamination is high

Example: Women from countries where leaded gasoline is still being used (or was recently phased out) or where industrial emissions are not well controlled.

Living near a point source of lead

Example: Lead mines, smelters, or battery recycling plants (even if the establishment is closed).

Working with lead or living with someone who does

Example: Women who work in or who have family members who work in lead industry (take-home exposures).

Using lead-glazed ceramic pottery

Example: Women who cook, store, or serve food in lead-glazed ceramic pottery made in a traditional process and usually imported by individuals outside the normal commercial channels.

Eating nonfood substances (pica)

Example: Women who eat or mouth nonfood items that may be contaminated with lead (such as soil or lead-glazed ceramic pottery).

Using alternative or complementary medicines, herbs, or therapies

Example: Women who use imported home remedies or certain traditional herbs that may be contaminated with lead.

Using imported cosmetics or certain food products

Example: Women who use imported cosmetics, such as kohl or surma, or certain imported foods or spices that may be contaminated with lead.

Engaging in certain high-risk hobbies or recreational activities

Example: Women who engage in high-risk activities or have family members who do.

Renovating or remodeling older homes without lead hazard controls in place

Example: Women who have been disturbing lead paint and/or creating lead dust or spending time in such a home environment.

Consumption of lead-contaminated drinking water

Example: Women whose homes have leaded pipes or source lines with lead.

Having a history of previous lead exposure or evidence of elevated body burden of lead

Example: Women who may have high body burdens of lead from past exposures, particularly those who are deficient in certain key nutrients (calcium, iron).

Living with someone identified with an elevated lead level

Example: Women who may have exposures in common with a child, close friend, or other relative living in the same environment.

Key Recommendations to Prevent or Reduce Lead Exposure

The CDC guidelines include general advice for pregnant women to avoid lead exposure (see Figure 11.2). Additional advice may be warranted due to specific local risk factors.

Figure 11.2. Key Recommendations to Prevent or Reduce Lead Exposure in Pregnant and Lactating Women

Never eat or mouth nonfood items, such as clay, soil, pottery, or paint chips, because they may be contaminated with lead.

Avoid jobs or hobbies that may involve lead exposure. If a household member works with lead, take precautions so they do not bring lead dust home. Such work includes construction or home renovation/repair in pre-1978 homes, and lead battery manufacturing or recycling.

Avoid using imported lead-glazed ceramic pottery produced in cottage industries and pewter or brass containers or utensils to cook, serve, or store food.

Avoid using leaded crystal to serve or store beverages.

Do not use dishes that are chipped or cracked.

Stay away from repair, repainting, renovation, and remodeling work being done in homes built before 1978 in order to avoid possible exposure to lead-contaminated dust from old lead-based paint. Avoid exposure to deteriorated lead-based paint in older homes.

Avoid alternative cosmetics, food additives, and medicines imported from overseas that may contain lead, such as azarcon, kohl, kajal, surma, and others.

Use caution when consuming candies, spices, and other foods that have been brought into the country by travelers from abroad, especially if they appear to be noncommercial products of unknown safety.

Eat a balanced diet with adequate intakes of iron and calcium.

Blood Lead Testing in Pregnancy and Early Infancy

Health care providers should consider the possibility of lead exposure in individual pregnant women by evaluating risk factors for exposure as part of a comprehensive occupational, environmental, and lifestyle health risk assessment of the pregnant woman. Blood lead testing should be performed if a risk factor is identified at any point during pregnancy.

When indicated, blood lead testing should take place at the earliest contact with the patient, ideally pre-conceptually or at the first prenatal visit, and be conducted using venous blood samples. Both maternal and infant blood lead test results, along with relevant environmental findings, should be incorporated into both the mother's and infant's medical records.

Follow-up Blood Lead Testing for Pregnant and Lactating Women and Infants

Follow-up blood lead testing is recommended for pregnant women with BLLs of 5 mcg/dL or greater and their newborn infants (see Tables 11.1, 11.2 and 11.3) to inform environmental and clinical decision-making. Pregnant women with confirmed BLLs of 45 mcg/dL and greater should be considered high-risk pregnancies and managed in consultation with experts in lead poisoning and high-risk pregnancy.

Table 11.1. Frequency of Maternal Blood Lead Follow-up Testing During Pregnancy

| Venous ^a Blood Lead Level (BLL) | Follow-up Testing Schedule ^b |
|--|--|
| < 5 | No follow-up is needed. |
| 5 – 14 | Within one month. Obtain a maternal BLL ^c or cord BLL at delivery. |
| 15 – 24 | Within one month and every two to three months. Obtain a maternal BLL ^c or cord BLL at delivery. More frequent testing may be indicated based on risk factor history. |
| 25 – 44 | Within one to four weeks and then every month. Obtain a maternal BLL ^c or cord BLL at delivery. |
| >= 45 | Within 24 hours and then at frequent intervals depending on the clinical interventions and trend in BLLs. Consultation with a clinician experienced in the management of pregnant women with BLLs in this range is strongly advised. Obtain a maternal BLL ^c or cord BLL at delivery. |

^a Venous blood lead sample is recommended for maternal blood lead testing.

^b The higher the BLL on the screening test, the more urgent the need for confirmatory testing.

^c If possible, obtain a maternal BLL prior to delivery since BLLs tend to rise over the course of pregnancy.

Table 11.2. Schedule for Follow-up Blood Lead Testing in Neonates (< 1 Month of Age)

| Initial Venous Blood Lead Level (BLL) ^a | Follow-up Test(s) ^b |
|--|--|
| < 5 | According to local screening guidelines for children |
| 5 – 24 | Within one month (at first newborn visit) ^c |
| 25 – 44 | Within two weeks, consultation with clinician experienced in the management of children with BLLs in this range ^d |
| >= 45 | Within 24 hours and then at frequent intervals depending on BLLs, consultation with experienced clinician ^d |

^a The initial blood lead level may be either from an umbilical cord sample at the time of delivery or an infant venous BLL. A venous blood sample is preferred over a capillary sample. Decisions to initiate or stop breastfeeding or initiate chelation therapy should be based on a venous blood lead test result only.

^b If infants are breastfeeding, also follow recommendations for lactating women.

^c According to pediatric health supervision guidelines (well-baby visit schedule) or as clinically indicated based on trends in BLLs.

^d The higher the BLL on the initial test, the more urgent the need for confirmatory testing.

Table 11.3. Schedule for Follow-up Blood Lead Testing in Infants < 6 Months of Age

| Venous Blood Lead Level (BLL) | Follow-up Testing ^{a, b} | Later follow up (after the BLL begins to decline) |
|-------------------------------|---|---|
| < 10* | According to local lead testing guidelines for children | According to the local lead screening guidelines for children |
| 10 – 14 | three months ^c | Within six to nine months |
| 15 – 19 | one to three months ^c | Within three to six months |
| 20 – 44 | one to three months ^d | Within one month |
| >= 45 | Within 24 hours ^d | As directed by clinician managing chelation treatment |

^aAfter six months of age, follow recommendations found in *Low Level Lead Exposure Harms Children: A Renewed Call for Primary Prevention*, Report of the Advisory Committee on Childhood Lead Poisoning Prevention of the Centers for Disease Control and Prevention, January 4, 2012

^bIf infants are breastfeeding, also follow the recommendations for lactating women.

^cSome case managers or primary care providers may choose to repeat blood lead tests on all new patients within a month to ensure that their BLLs are not rising more quickly than anticipated. Seasonal variation of BLLs exists and may be more apparent in colder climate areas. Greater exposure in the summer months may necessitate more frequent follow-ups.

^dConsultation with a clinician experienced in the management of children with BLLs in this range is strongly advised.

*These recommendations are based on the previous action level of 10 mcg/dL.

Recommended Actions for Pregnant and Lactating Women with Lead Exposure

Both the local health department and health care provider can play a role in keeping pregnant and lactating women and their offspring safe from lead exposure. Table 11.4 includes key recommendations from the CDC (2010) for the management of pregnant and lactating women by prenatal blood lead level.

Table 11.4. Recommended Actions by Blood Lead Level in Pregnancy

| BLL | Health Care Providers | Public Health Providers |
|-------|---|---|
| < 5 | Provide anticipatory guidance and health education materials to all pregnant and lactating women. | <ul style="list-style-type: none"> • Collect all blood lead tests • Develop and disseminate guidelines and health education materials to clinicians • Provide community-specific risk factors and population-based blood lead testing guidance to clinicians |
| 5 – 9 | <p><i>Above actions plus</i></p> <ul style="list-style-type: none"> • Attempt to determine source(s) of lead exposure and counsel patients on strategies to reduce exposure • For occupationally exposed women, review proper use of personal protective equipment and consider contacting the employer • Assess nutritional adequacy • Confirmatory and follow-up testing (see Table 11.1) | <i>As above</i> |

| BLL | Health Care Providers | Public Health Providers |
|--------------------|---|--|
| 10–14 | <i>Above actions plus</i> <ul style="list-style-type: none"> • Notify lead poisoning prevention program of local health department if not reported by the laboratory • Refer occupationally exposed women to occupational medicine specialists • For occupationally exposed women, recommend removal from exposure | <i>Above actions plus</i> <ul style="list-style-type: none"> • Send out health education materials to patient • For occupationally exposed women, remove from exposure |
| 15–44 ^a | <i>Above actions plus</i> <ul style="list-style-type: none"> • Assist local health departments with complete source exposure assessment | <i>Above action plus</i> <ul style="list-style-type: none"> • Perform or refer for environmental investigation, source reduction/lead hazard control, case management |
| ≥45 ^b | <i>Above actions plus</i> <ul style="list-style-type: none"> • Treat as high-risk pregnancy • Consider chelation (inpatient) in consultation with a lead poisoning expert | <i>Above action plus</i> <ul style="list-style-type: none"> • Facilitate consultation with a lead poisoning expert experienced in managing chelation in pregnant women |

^aEnvironmental interventions to control lead exposures at blood lead levels below those in this chart support the goal of lead-safe housing for all children and are appropriate in jurisdictions with resources available to provide such services.

^bBlood lead levels ≥ 70 mcg/dL may result in significant maternal toxicity; therefore, chelation should be considered regardless of trimester of pregnancy and in consultation with an identified lead poisoning expert.

Breastfeeding and Lead Exposure

Human breast milk is specific to the needs of the infant and is the most complete and ideal source of infant nourishment in the first year of life. Decisions made with regard to breastfeeding by a mother whose blood lead levels exceed background levels should be based on scientific evidence suggesting undue risk for the child. Scientific observations have consistently shown that biologically significant elevations in milk lead concentration do not occur in lactating women at the blood lead concentrations typical of women with long-term residence in developed countries. Only a small number of American women will meet the criteria to defer breastfeeding, though more will be subject to additional follow up out of an abundance of caution.

The overall goal in counseling a woman whether or not to breastfeed is to provide the best possible nutritional and nurturing environment for the infant. Any decision either not to initiate or to discontinue breastfeeding must be made only after careful consideration of all the factors involved. The basis of the initial decision-making process should include a thorough discussion between the mother and her health care provider of the factors to be considered. This discussion should ideally take place before the baby is born. Many factors have an impact on whether or not a woman with a blood lead level ≥ 5 mcg/dL chooses to breastfeed her child. Thus, a detailed and balanced discussion is essential.

Lead in Breast Milk

The concentration of lead in breast milk is linked to the concentration of lead in the maternal blood. The total amount of lead in breast milk is stable over time and is determined by the mother's lifetime exposure and body burden of lead. The contribution of lead in breast milk to infant exposure to lead is usually less important than prenatal and other postnatal exposures. Infant blood lead levels primarily reflect maternal blood lead levels. Lead in breast milk contributes modestly to infants overall lead exposure, explaining 30 percent of the variance in infant blood lead levels at one month of age. The benefits of breastfeeding will most often outweigh concerns about infant exposure to lead from breast milk.

Several studies show breast milk lead to maternal blood lead ratios of approximately 3 percent or less (Gulson et al., 1998, Li et al., 2000, and Counter et al. 2004). Thus a maternal blood lead of 100 mcg/dL would be expected to be associated with a concentration of 3 mcg/dL lead in breast milk. Similarly, a blood lead of 10 mcg/dL would be expected to be associated with a breast milk lead concentration of 0.3 mcg/dL. A more recent study found blood lead and plasma lead have nonlinear relationships to breast milk lead (Ettinger et al., 2006).

The amount of any substance transferred from blood to breast milk is dependent on its solubility and binding affinities. Lead is an ionized metal, bound tightly to red blood cells, and is found at low levels in the plasma. These characteristics inhibit transfer of lead into breast milk.

The *half-life* of a chemical substance refers to the amount of time required for a quantity to fall to half its value as measured at the beginning of the time period. This idea is often used when evaluating the effect of a dose of a specific medication or a poisoning incident. The long half-life of lead in breast milk (13 weeks) is due to bone stores of lead that can be mobilized, move into the blood, and become available for transfer into breast milk.

Evidence suggests that the breast milk lead to maternal blood lead ratio may increase in a nonlinear fashion when maternal blood lead concentrations exceed about 40 mcg/dL. This hypothesis is supported both by observational data on women with very high breast milk lead concentrations (Li et al., 2000; Namihara et al., 1993) and by studies on the components of the blood (e.g., plasma) and breast milk as they relate to maternal lead exposure (Hernandez-Avila et al., 1998; Manton and Cook, 1984; Manton et al., 2001; O'Flaherty, 1993; Schutz et al., 1996). A finding that breast milk contains proportionally more maternal lead at higher blood lead levels suggests possible risk associated with breastfeeding at maternal blood lead levels above 40 mcg/dL.

For lactating women with a history of past high lead exposure and low dietary calcium intake, a randomized trial showed that providing calcium supplements lowered blood lead levels in lactating women (Hernandez-Avila et al., 2003). For such women, calcium supplements could be expected to protect children by lowering the lead in breast milk.

Most recent studies measuring lead in breast milk of the general population have found the average level has been in the lower end of a range from 0.1 to 2 mcg/dL (100 cc) of breast milk (American Academy of Pediatrics, 2005, Ettinger et al., 2014). The decline in these averages is believed to correspond with the decline in BLLs of the general population.

At this time, there is no laboratory in Wisconsin that can do routine analysis of lead content in breast milk. For more information, health care providers can call the Wisconsin State Laboratory of Hygiene (608-224-6252).

Infant Dose of Lead from Breast Milk

Using the lower average amount of lead in breast milk (0.1 mcg/dL) and an average intake of breast milk of 700 cc (24 oz.), a daily dose of 0.7 mcg of lead/day can be estimated. This would be considered a low level of dietary lead intake, and a considerable drop from the U.S. Food and Drug Administration Total Diet Study estimate of infants' daily lead intake of approximately 5 mcg. The amount of lead in breast milk will be relatively stable during nursing.

Recommendations for Lactating Women with Lead Exposure

On the basis of the health and developmental benefits to infants of breastfeeding, and consideration of the available research on the contribution of breast milk lead to infant blood lead, CDC has developed clinical guidance for breastfeeding by women exposed to lead. Initial criteria for breastfeeding are maternal blood lead levels, but ongoing monitoring of infant blood lead levels provides the additional feedback loop needed for clinical decision making about continuing breastfeeding. Specifically, a rise in infant BLL of 5 mcg/dL or more is regarded as clinically significant and affects breastfeeding recommendations. Testing recommendations for women with BLL ≥ 5 mcg/dL identified during pregnancy or at delivery were presented previously in Table 11.1 and for infants in Tables 11.2 and 11.3. Measurement of breast milk lead is not recommended given current laboratory methods and the availability of maternal blood lead as a proxy.

Initiation of breastfeeding should be encouraged for all mothers with blood lead levels < 40 mcg/dL, with follow-up recommendations varying by blood lead levels. Initial maternal BLLs < 20 mcg/dL are unlikely to be associated with a detectable increase in infant blood lead, even using a ratio of breast milk to maternal blood 10 times the most likely value, as in the above calculations. In women with BLLs between 5-19 mcg/dL, an initial infant blood lead level is warranted to establish a baseline.

At maternal blood lead levels between 20-39 mcg/dL, data do not exist to weigh accurately the risks of lead exposure from breast milk against the benefits of breastfeeding. Thus, a prudent course of action is for these women to initiate breastfeeding accompanied by sequential mother and infant blood lead levels to monitor trends, so that adjustments can be made if indicated. Mothers with BLL between 20-39 mcg/dL should be retested two weeks postpartum and then at one to three-month intervals, depending on the direction and magnitude of trend in infant blood lead levels (Table 11.5).

CDC considered the adverse health and developmental effects associated with lead exposure compared to those associated with not breastfeeding and, based on the available information, determined that at maternal blood lead levels ≥ 40 mcg/dL the adverse developmental effects of an increase of ≥ 5 mcg/dL in an infant's blood lead level was of greater concern than the risks of not breastfeeding until maternal blood lead level dropped to < 40 mcg/dL. Mothers with blood lead levels ≥ 40 mcg/dL should not initiate breastfeeding immediately. They should be advised to pump and discard their breast milk until their blood lead levels drop below 40 mcg/dL. In such cases, infants' blood lead levels should be monitored after the initiation of breastfeeding. This recommendation reaffirms the prevailing guidance about deferring breastfeeding at maternal BLL ≥ 40 mcg/dL.

For breastfed infants whose blood lead levels are rising or failing to decline by 5 mcg/dL or more, environmental and other sources of lead exposure should be evaluated. If no external source is identified, and maternal BLLs are > 20 mcg/dL and infant BLL are ≥ 5 mcg/dL, then breast milk should be suspected as the source, and temporary interruption of breastfeeding until maternal blood lead levels decline should be considered. There are insufficient data to estimate how many mother-child pairs would meet these criteria, but anecdotal evidence suggests that it would apply to a very small number in the United States.

Table 11.5. Frequency of Maternal Blood Lead Follow-up Testing During Lactation^a to Assess Risk for Infant Lead Exposure^b from Maternal Breast Milk

| Initial ^c Venous ^d Blood Lead Level | Perform Follow-up Blood Lead Test(s) |
|---|--|
| 5 – 19 | Every three months, per guidelines for adult blood testing, unless infant BLLs are rising or failing to decline ^e |
| 20 – 39 | Two weeks postpartum and then at one to three-month intervals depending on direction/magnitude of trend in infant BLLs |
| >= 40 | Within 24 hours postpartum and then at frequent intervals depending on clinical interventions and trend in BLLs Consultation with a clinician experienced in the management of lead poisoning is advised. |

^aIf a woman becomes pregnant while lactating, she should be followed according to the schedule for pregnancy.

^bNeed to coordinate care between mother and infant in postpartum period.

^cLast blood lead level measured in pregnancy or at delivery (maternal or cord blood).

^dVenous blood lead sample is recommended for maternal blood lead testing.

^eInfant should be monitored according to schedule in Tables 11.2 and 11.3.

The content of this chapter is from the *Guidelines for the Identification and Management of Lead Exposure in Pregnant and Lactating Women*, CDC, 2010.

References

- American Academy of Pediatrics. "Breastfeeding and the Use of Human Milk." *Pediatrics*, 2005, 111, pp. 496-506.
- Borja-Aburto V. H., Hertz-Picciotti, I., Rojas Lopez, M., Farias, P., Rios, C., Blanco, J. "Blood Lead Levels Measured Prospectively and Risk of Spontaneous Abortion." *American Journal of Epidemiology*, 1999 150(6), pp. 590-7.
- Bressler, J. P., Goldstei, G. W. "Mechanisms of lead neurotoxicity." *Bio Chem Pharmacol*, 1991, 41(4), pp. 479-484.
- Cory-Sletcha, D. A. "Relationship between Pb-induced changes in neurotransmitter system function and behavioral toxicity." *Neurotoxicology*, 1997, 18(3), pp. 673-688.
- Counter, S. A., Buchanan, L. H., Ortega, F. "Current Pediatric and Maternal Lead Levels in Blood and Breast Milk in Andean Inhabitants of a Lead Glazing Compound." *J Occup Environ Med*, 2004, 46 (9), pp. 967-973.
- Ettinger, A. S. and Wengrovitz, A. G., editors. "Guidelines for the Identification and Management of Lead Exposure in Pregnant and Lactating Women," Centers for Disease Control and Prevention, November 2010.
- Ettinger, A. S., Roy, A., Amarasiriwardena, C. J., Smith, D., Lupoli, N., Mercado-Garcia, A., Lamadrid-Figueroa, H., Tellez-Rojo, M. M., Hu, H., Hernandez-Avila, M. "Maternal Blood, Plasma, and Breast Milk Lead: Lactational Transfer and Contribution to Infant Exposure." *Environmental Health Perspectives*, 2014, 122 (1), pp 87-92.
- Ettinger, A. S., Tellez-Rojo, M. M., Amarasiriwardena, C. J., Schwartz, J., Peterson, K. E., Aro, A. "Influence of Maternal Bone Lead Burden and Calcium Intake on Levels of Lead in Breast Milk Over the Course of Lactation." *Am J Epidemiology*, 2006, 163, pp. 48-56.
- Gonzalez-Cossio, T., Peterson, K. E., Sanin, L. H., Fishbein E., Palazuelos, E., Aror, A., et al. "Decrease in Birth Weight in Relation to Maternal Bone-Lead Burden." *Pediatrics*, 1997, 100(5), pp. 856-962.
- Goldstein, G. W. "Lead Poisoning and Brain Cell Function." *Environmental Health Perspectives*, 1990, 89, pp. 91-94.
- Goldstein, G. W. "Neurologic Concepts of Lead Poisoning in Children." *Pediatric Annals*, 2002, pp. 384-388.
- Gomaa, A., Hu, H., Bellinger, D., Schwartz J., Tsaih, S. W., Gonzalez-Cossio, T. et al. "Maternal Bone Lead as an Independent Risk Factor for Fetal Neurotoxicity: a Prospective Study." *Pediatrics*, 2002, 100(1 Pt. 1), pp. 110-118.
- Guerra-Tamayo, J. L., Hernandez-Cadena, L., Tellez-Rojo, M. M., Mercado-Garcia A. S., Solano-Gonzalez, M., Hernandez-Avila, M., et al. "Time to Pregnancy and Lead Exposure." *Salud Publica Mex 45 Suppl*, 2003, 2, pp. 189-195.

Guilart, T. R., Miceli, R. C., Jett, D. A. "Neurochemical Aspects of Hippocampal and Cortical Pb²⁺ Neurotoxicity." *Neurotoxicology*, 1994, 15(3), pp. 459-466.

Gulson, B. L., Jameson, C. W., Mahaffey, K. R., Mizon, K. J., Patison, N, Law, A. J., et al. "Relationships of Lead in Breast milk to Lead in Blood, Urine, Diet of the Infant and Mother." *Environmental Health Perspectives*, 1998, 106(10), pp. 667-674.

Gump, B. B., Stewart, P., Reihman, J., Lonky, E., Darvill, T., Parsons, P. J., et al. "Low-Level Prenatal and Postnatal Blood Lead Exposure and Adrenocortical Responses to Acute Stress in Children." *Environmental Health Perspectives*, 2008, 116(2), pp. 249-255.

Hernandez-Avila, M., Gonzalez-Cossio, T., Hernandez-Avila, J. E., Romieu, I., Peterson, K. E., Aro A, et al. "Dietary Calcium Supplements to Lower Blood Lead Levels in Lactating Women, a Randomized Placebo-Controlled Trial." *Epidemiology*, 2003, 14, pp. 206-212.

Hernandez-Avila, M., Peterson K. E., Gonzalez-Cossio, T., Sanin, L. H., Aro, A, Schnaas, L., et al. "Effects of Maternal Bone Lead on Length and Head Circumference of Newborns and 1-Month Old Infants." *Archives of Environmental Health*, 2002, 57(5), pp. 482-488.

Hernandez-Avila, M., Smith, D., Meneses, F. Sanin, L. H., Hu, H. "The Influence of Bone and Blood Lead on Plasma Lead Levels in Environmentally Exposed Adults." *Environmental Health Perspectives*, 1998, 106(8), pp. 473-477.

Hu, H. "Knowledge of Diagnosis and Reproductive History Among Survivors of Childhood Plumbism." *American Journal of Public Health*, 1991, 81, pp. 1070-1072.

Jackson, L. W., Correa-Villasenor, A., Lees, P. S., Dominici, F., Stewart, P. A., Breyse, P. N., et al. "Parental Lead Exposure and Total Anomalous Pulmonary venous return." *Birth Defects Res*, 2004, 70-(4), pp. 185-193.

Jedrychowski, W., Perera, F., Jankowski, J., Rauh, V., Flak, E., Caldwell, K. L., et al. "Prenatal Low-Level Lead Exposure and Developmental Delays in Children at Age 6 Months." *International Journal of Hygienic Environmental Health*, 2008, 211(3), pp. 345-351.

Jelliffe-Pawlowski, L. L. "Effect of Magnitude and Timing of Maternal Pregnancy Blood Lead (Pb) Levels on Birth Outcomes." *Journal of Perinatology*, 2006 26(3), pp. 154-62.

Kennedy DA, Woodland C, Koren G. "Lead Exposure, Gestational Hypertension, and Pre-Eclampsia: A Systematic Review of Cause and Effect." *Journal of Obstetrics and Gynaecology*, 2012, 32, pp. 512-517.

Lamadrid-Figueroa, H., Tellez-Rojo, M. M., Hernandez-Avila, M., Trejo-Valdiva, B., Solano-Gonzalez, M., Mercado-Garcia, A., et al. "Association between Plasma/Whole Blood Lead Ratio and History of Spontaneous Abortion: a Nested Cross-Sectional Study." *BMC Pregnancy Childbirth*, 2007, 7, p. 22.

Li, P. J., Sheng, Y. Z., Wang, Q. Y., Gu L. Y. "Transfer of Lead Via Placenta and Breast Milk in Humans. *Biomedical Environmental Science*, 2000, 13(2), pp. 85-89.

Magri, J., Sammut, M., Savona-Vebntura, C. "Lead and Other Metals in Gestational Hypertension." *Scandinavian Journal of Work and Environmental Health*, 2003, 83(1), pp. 29-36.

Manton, W. I., Cook, J. D. "High Accuracy (stable isotope dilution) Measurements of Lead in Serum and Cerebrospinal Fluid." *British Journal of Industrial Medicine*, 1984, 41(3), pp. 313-319.

Manton, W. I., Rothenberg, S. J., Manalo, M. "The Lead Content of Blood Serum." *Environmental Research*, 2001, 86(3), pp. 263-273.

Namihara, D., Saldivar, L., Pustilnik, N., Carreon, C. G., Salinas, M. E. "Lead in Human Blood and Milk from Nursing Women Living Near a Smelter in Mexico City." *Journal of Toxicology and Environmental Health*, 38(3), pp. 225-233.

O'Flaherty, E. J. "Physiologically Based Models for Bone-Seeking Elements. IV. Kinetics of Lead Disposition in Humans." *Toxicology and Applied Pharmacology*, 1993, 118(1), pp. 16-29.

Rabinowitz, M., Bellinger, D., Leviton, A., Needleman, H., Shoenbaum, S. "Pregnancy Hypertension, Blood Pressure During Labor and Blood Lead Levels." *Hypertension*, 1987, 10(4), pp. 447-451.

Ris, M.D., Dietrich, K. N., Succop, P. A., Berger, O. G., Bornschein, R. L. "Early Exposure to Lead and Neuropsychological Outcome in Adolescence." *Journal of International Neuropsychology and Sociology*, 2004, 10(20), pp. 261-270.

Rodamilans M, Osaba MJ, To-Figueras J, Rivera Fillat F, Marques JM, Perez P, Corbella J. Lead toxicity on endocrine testicular function in an occupationally exposed population. *Human Toxicology*, 1988; 7(2), pp. 125-8.

Rothenberg, S. J., Manalo, M., Jiang, J., Cuellar, R. Reyes, S., Sanchez, M. et al. "Blood Lead Level and Blood Pressure During Pregnancy in South Central Los Angeles." *Archives of Environmental Health*, 1999, 56(4), pp. 382-389.

Rothenberg, S. J., Poblano, A., Garza-Morales, S. "Prenatal and Perinatal Low Level Lead Exposure Alters Brain Stem Auditory Evoked Responses in Infants." *Neurotoxicology*, 1994, 15(3), pp. 695-699.

Schnaas, L., Rothenberg, S. J., Flores, M. F., Matrinez, S., Hernanadez, C., Osorio, E., et al. "Reduced intellectual Development in Children with Prenatal Lead Exposure." *Environmental Health Perspectives*, 114(5) pp. 791-797.

Schultz, A., Bergdahl, I. A., Ekholm, A., Skerving, S. "Measurement by ICM-MS of Lead in Plasma and Whole Blood of Lead Workers and Controls." *Occupational and Environmental Medicine*, 1996, 53(11), pp. 736-740.

Sowers, M. R., Scholl, T. O., Hall, G., Jannausch, Kemp, F. W., Li, X., et al. "Lead in Breast Milk and Maternal Bone Turnover." *American Journal of Obstetrics and Gynecology*, 2002, 187(3), pp. 770-776.

Terrez-Rojo. M., Hernandez-Avila, M., Gonzalez-Cossio, T., Romieu, I., Aro, A., Palazuelos E, et al. "Impact of Breastfeeding on the Mobilization of Lead." *American Journal of Epidemiology*, 155(5), pp. 420-428.

Torrez-Sanchez, I. E., Berkowitz, G., Lopez-Carrillo, L., Torres-Arreola, L., Rios, C., Lopez-Cervantes, M. "Intrauterine Lead Exposure and Preterm Birth." *Environmental Research*, 1999, 81(4), pp. 297-301.

Vigeh, M., Yokoyama, K., Mazaheri, M., Beheshti, S., Ghazizadeh, S., Sakai, T., et al. "Relationship Between Increased Blood Lead and Pregnancy Hypertension in Women without Occupational Lead Exposure in Tehran, Iran." *Archives of Environmental Health*, 2004, 59(2), pp. 70-75.

Wasserman, G. A., Liu, X., Popovac, D., Factor-Litvak, P., Kline, J., Waternaux, C, et al. "The Yugoslavia Prospective Lead Study: Contributions of prenatal and perinatal lead exposure to early intelligence." *Neurotoxicology and Teratology*, 22(6), 2000, pp. 811-818.

West, W., Knight, E., Edwards, C., Manning, M., Spurlock, B., Hutchinson, J., Johnson, A., Oyemade, U., Cole, D., Westney, O., Laryea, H., Jones, S., and Westney, L. "Maternal Low Level Lead and Pregnancy Outcomes." *American Institute of Nutrition*, 0022-3166, 9815-9865, 1994.

Wigg, N. R., Vimpani, G. V., McMchael, A. J., Baghurst, P. A., Robertson, E. F., Roberts, R. J. "Port Pirie Cohort Study: Childhood Blood Lead and Neuropsychological Development at Age Two Years." *Journal of Epidemiology and Community Health*, 1988, 42, pp. 213-219.

Wu, T., Buck, G. M., Mendola, P. "Blood Lead Levels and Sexual Maturation in U.S. Girls: The Third National Health and Nutrition Examination Survey, 1998-1994." *Environmental Health Perspectives*, 2003, 111(5), pp. 737-741.

Zhu M., Fitzgerald E. F., Gelberg, K. H., Lin S., Druschel C. M. "Maternal Low-Level Lead Exposure and Fetal Growth." *Environmental Health Perspectives*, 2010, 118; 10, pp. 1471-1475.